Global Cycles of Methane, Nitrogen, and Phosphorous

Methane (CH_4)

- Methane is a minor component of the earth's carbon budget (10^{13} to 10^{14} g /year)
- It's present atmopsheric concentration is 1.7 ppmv
- Compared to carbon dioxide it is 20 time more effective at trapping longwave energy
- It is increasing at a whopping 1% per year in the atmosphere
- The average residence time in the atmosphere is 10 years
- The concentration is slightly higher in the northern hemisphere than the southern hemisphere giving a good indication that the northern hemisphere is important in global methane fluxes

Why is methane increasing in the atmosphere?

This is a very good question. Most of the annual production of methane is natural (500 x 10^{12} g / year). The major sources of methane are anaerobic decomposition of organic matter in natural wetlands (115 x 10^{12} g /year). 60% of this total comes from peat bogs at high latitudes (50°-70° N), while tropical wetlands (10°S to 10°N) are also important sources.

Thus changes in the distribution of wetlands obviously will have large effects on the global methane cycle. While natural wetlands are being drained some new wetlands may be being created.

The worldwide cultivation of rice may be very important as:

1. there are high methane fluxes from rice paddies
2. the area covered by rice paddies would be expected to grow
3. much of this growth will occur in low-latitudes where processes producing methane can occur through a much longer portion of the year than processes occurring high latitude wetlands

There is a strong seasonal cycle in the amount of methane in the atmosphere. The maximum does not occur in midsummer as might be expected for carbon dioxide. This is potentially due to increasing oxygen in wetlands during this time due to higher concentrations of algae, which increase the amount of oxidation in these environs.

Other methane sources

- Cows are major methane emitters so the more cows the more methane – a good reason to become a vegetarian.

- Termites were also thought to be major emitters, but recent estimates have lowered this source.
- Oceans are a minor source
- Inadvertent release of methane in the production of natural gas is also a fairly large source.

Sinks
Despite the increase of methane fluxes, it appears that these increases are not enough to explain the observed rise in atmospheric methane. So the increase in atmospheric methane may be due to a decrease in the rate that methane is being destroyed in the atmosphere (the major methane sink at 490 x 10^{12} g /year). The actual process of destroying methane is complex, but in simple terms it involves reactions with OH. Basically reactions with methane and carbon monoxide (CO) consume nearly all free OH radicals in the atmosphere. Thus as carbon monoxide increases due to human activity, the destruction of methane may be slowed as a result.

Aerobic bacteria also consume methane in soils. The rate of this consumption appears to be controlled by the rate at which methane is able to diffuse in soils. This sink appears to be about 10 x 10^{12} g/year and may be decreasing because of changes in tropical land use.

However, the actual question of why atmospheric methane is increasing remains unsolved.

Carbon Monoxide (CO)

5% of the total carbon released is in combustion is in the form of carbon monoxide, but overall CO is only a minor contribution to the global carbon cycle.

½ of the global production of CO is from fossil fuels and biomass burning.

Fortunately, the atmospheric lifetime of CO is very short, 60 days so it is a minor greenhouse gas, and the concentrations are much lower in the Southern Hemisphere.

Nitrogen (N)

Reservoirs

- Atmosphere 3.8×10^{21} g N (20 – 100 Million year residence time)
- Biomass 3.5×10^{15} g N (625 year residence time)
- Soils 95×10^{15} g N (50 year residence time)

Basically the pool of inorganic nitrogen (NH_4^+ and NO_3^-) is small and despite a high flux, the large uptake of plants keeps these reservoirs small. The big problem for biota is that triple bond holding the N_2 molecule together.

The Nitrogen Cycle

[Examine the nitrogen cycle in the handout]

Some things to remember, tremendous amounts of recycling of Nitrogen occur in both the terrestrial and marine ecosystems as this vital nutrient is efficiently recycled while in a usable form to biota. The processes of biological fixation and denitrification are important fluxes for both the atm-land and atm-ocean fluxes.

Human Activities

Humans have a significant impact on the nitrogen cycle.

- Production of fertilizer (40×10^{12} g N /year)
- Car exhaust (40 to 60×10^{12} g N /year). Most of this ends up precipitating on land.

These two sources have significant human impacts on both ground and surface water pollution, as there are high concentrations of nitrates in many areas. Rivers carry 36×10^{12} g N / year of which up to 7×10^{12} g N / year may be from human sources.

Phosphorous (P)

- No significant atmospheric component
- Not driven by microbial activity
- Nearly all of the P on land originally comes from phosphate minerals, mainly apatite ($Ca_5(PO_4)_3OH$.
- Most P is carried by rivers as particulate and not dissolved matter (21×10^{12} g P / year). Human activities have played a large role in increasing the amount of P in river systems.
- Phosphate (PO_4^{3-}) in the oceans is a huge pool, though concentrations are low. The residence time in long 4000-80,000 years, however turnover time in the organic pool at the surface is fast, only a few days as P is a limiting nutrient so it is efficiently recycled.
- The phosphorous cycle is largely a geologic one with P stored in ocean sediments which are then placed on the land to weather away and sent back to the ocean to complete the cycle. However, the cycle has had immense human influence due to the use of P as a fertilizer.